Documentation of creation of Aqua RSRs

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Contents

1 Abstract

This report documents the choices made for the creation of the Aqua RSRs to be used for the Aqua processing by the SeaWiFS group and shows the resulting RSRs.

2 Introduction

MCST has made available the following RSR (relative spectral response) datasets, measured and processed by SBRS:

1. Aqua in-band RSR (down to 1% from maximum) for each detector (about 1nm intervals)
2. 2 versions of Aqua out-of band RSR for detector 5 (at 10 nm intervals): one normalized to the in-band maximum, the other normalized to the Spectral Measurement Assembly (the latter is probably an absolute normalization).

3. Terra in-band RSR for each detector (wider range than Aqua in-band) for each detector (about 1nm intervals)

4. Terra out-of-band RSR averaged over all detectors (for most bands, some bands with detector specific out-of-band RSRs) (at 10 nm intervals)

The center wavelength using the MCST-provided Aqua out-of-band RSRs normalized to the in-band maximum differs significantly (about 3nm) from the centerwavelength using the Aqua out-of-band RSRs normalized to the Spectral Measurement Assembly (SpMA) for band 8. Since we need a consistent RSR over the whole spectrum and do not need a specific normalization (the normalization cancels in the calculation of the band-averaged values), the only possible choice is the out-of-band RSR normalized to the in-band RSR. This is also the choice made by the MOBY team. It is however disturbing that the Aqua RSRs normalized to the in-band are quite different from the Terra RSR, whereas the Aqua RSRs normalized to the SpMA are very similar to the Terra RSR. A comparison of the three different RSRs is shown in the appendix, Figs. 13 to 21. The center wavelengths for all datasets (including the Aqua RSR created to be used for the SeaWiFS group) are given in table 1 on page 18 in the appendix. The variations between the datasets are usually less than 1nm between the datasets for the bands 9-16. *The Aqua RSR dataset created for the SeaWiFS group uses the Aqua out-of-band RSRs normalized to the in-band.*

The Aqua out-of-band measurements presumably have a wider bandwidth than the Aqua in-band measurements. This is probably the reason why in many bands the out-of-band measurements on the border to the in-band are significantly higher than the in-band measurement on the border, see e.g. Band 8 shown in Fig. 1. There is no data available regarding the bandwidth of the RSR measurements, thus *the out-of-band measurements bordering the in-band were discarded.*

In an internal meeting on 10/29/03, it was agreed to:

- Create an RSR data set at 1nm intervals.
- Use the wavelength range from 350nm to 1100nm (MCST provides the data in that range).
- Use cubic spline interpolation for the in-band values.

The following choices had to be tested for the creation of the Aqua RSRs:

- Can outliers that are below the typial values (e.g. at 1e-15, well below the assumed instrument responsivity) be ignored ? (see section 4.3)
- Does it make a significant difference if the transition between in-band and out-of-band data is interpolated linearly in log-space or if smoothed Terra in-band data is used ? (see section 4.2)

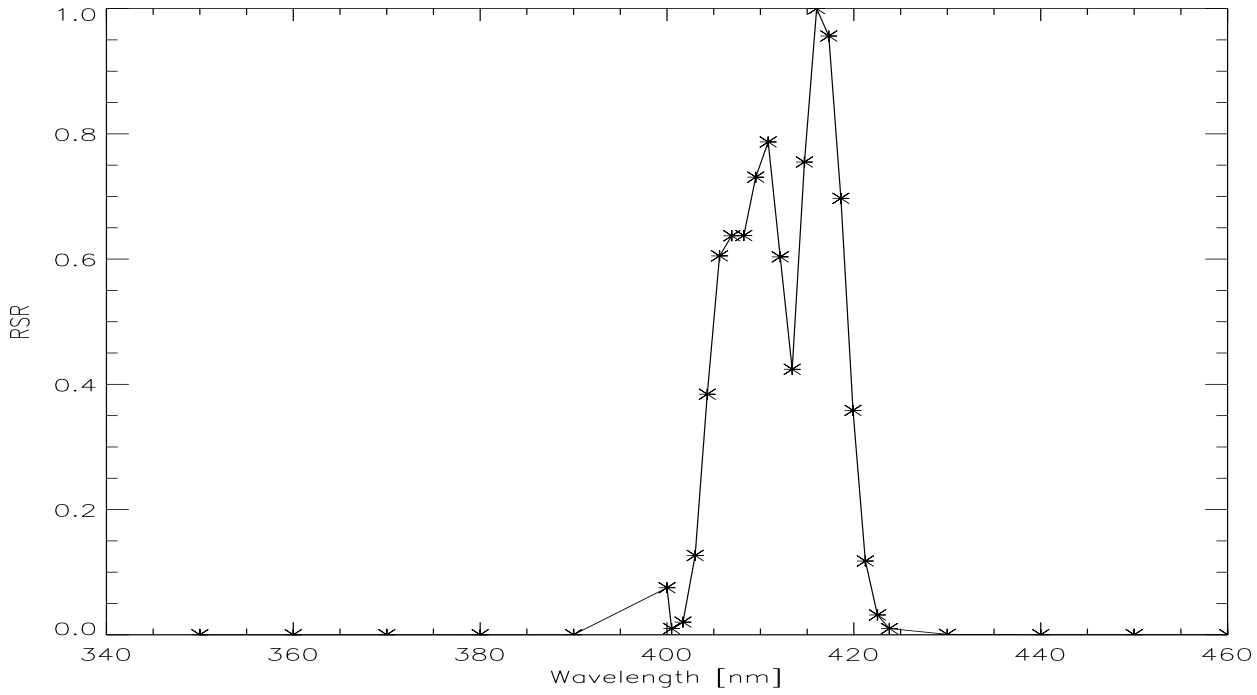

Figure 1: RSR of Aqua Band 8 as provided by MCST (merged in-band/out-of-band). At 400 nm, the value of the out-of-band measurements is very likely influenced by the in-band RSRs.

- What is the difference when interpolating the data in the out-of-band versus assuming a step function ? (see section 4.1)
- Does a linear interpolation of the out-of-band data give the same results as a linear interpolation in logspace (base 10) ? The linear-in-logspace interpolation looks better in plots, but a conventional linear interpolation may be more physically accurate. (see section 4.2)
- What is the effect of averaging all in-band detector RSRs to a single band RSR ? (see section 4.4)

A difference of 0.1% or more in band averaged values is considered signifcant. Six different spectra were used to evaluate the differences in all 9 MODIS Ocean bands.

3 Method

Six different spectra were used to evaluate the differences in the band averaged values in all 9 MODIS Ocean bands. They are shown in Fig. 2. The spectra are

- Thuillier 2003
- Neckel and Labs
- 3 nLw at different chlorophyll concentrations (chl=0.01,1,10, provided by Sean)
- TOA open ocean spectrum (provided by Bob, Spectra3.dat)

The spectra were provided by Bob Barnes interpolated to 1nm intervals.

A band averaged value (S_{ba}) is calculated from the spectrum $S(\lambda)$ and the RSRs $r(\lambda)$ by

$$S_{ba} = \frac{\int_{\lambda=350nm}^{\lambda=1100nm} S(\lambda) \cdot r(\lambda) d\lambda}{\int_{\lambda=350nm}^{\lambda=1100nm} r(\lambda) d\lambda} \quad (1)$$

In practice, the spectra $S(\lambda)$ were interpolated to the same wavelengths as the RSRs, the product with $r(\lambda)$ was summed over all wavelengths and divided by the sum of $r(\lambda)$.

4 Results

4.1 Border in-band/out-of-band

The differences of the band averaged values using the Terra data at the border in-band/out-of-band versus using the interpolated Aqua data are insignificant for all bands and spectra.

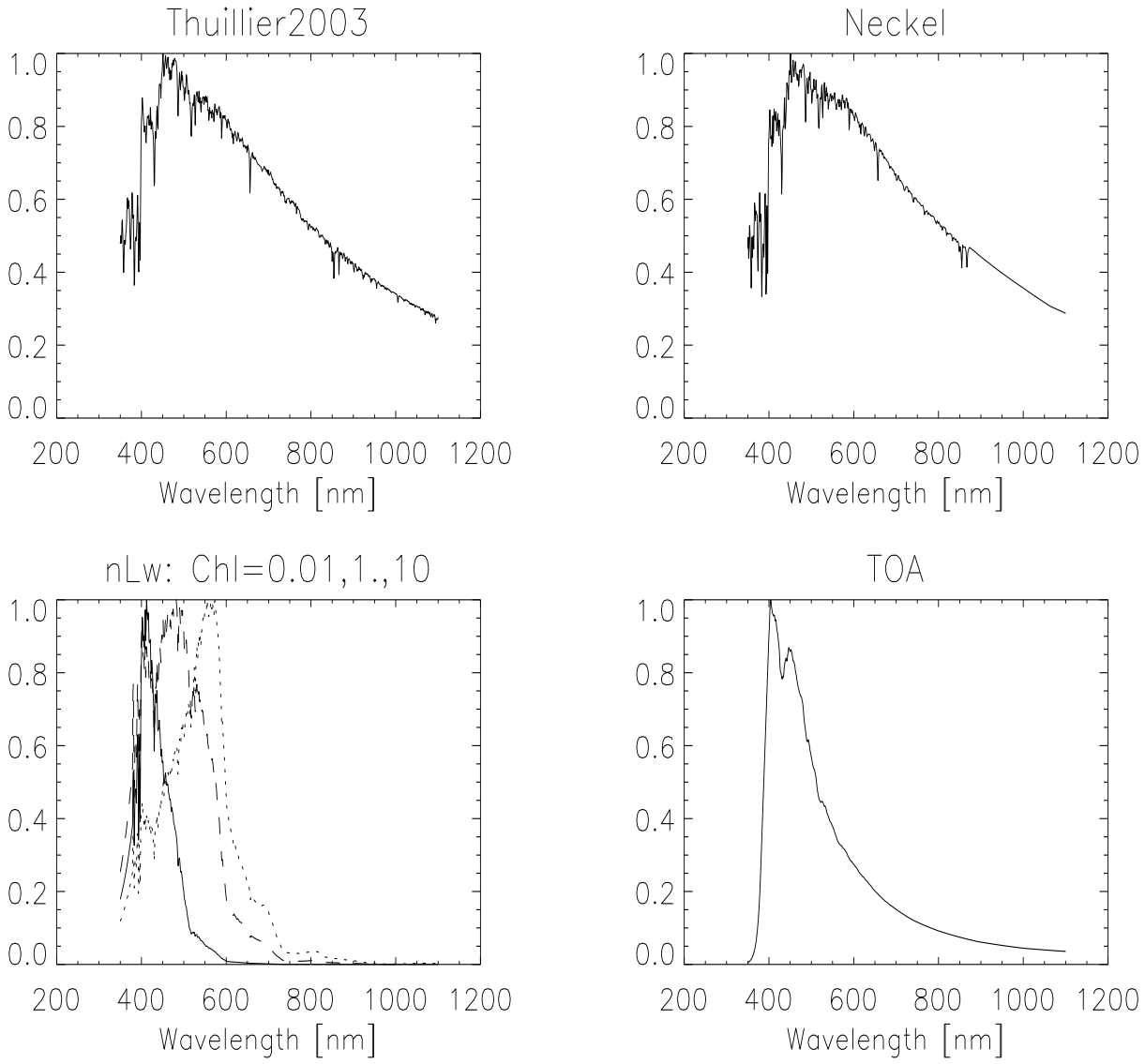

Figure 2: Input spectra for the calculation of the band averaged values, normalized to the maximum value.

4.2 Linear versus Loglinear interpolation

All the differences were 0.15% or less, except for the nLw spectra in the NIR (bands 15 and 16, up to 1.5%). As these spectra have an almost zero NIR intensity anyway, these results are not alarming. Band averaged values calculated with a constant value in every 10nm interval (provided by Bob Barnes) in the out-of-band region yielded very similar results as when the out-of-band values were interpolated with both methods.

4.3 Smoothing over outliers

Significant differences were only found in NIR bands with negligible radiances, see above.

4.4 Single band RSR

The differences in the band averaged values for the 10 detector specific in-band RSRs are highest in band 8 with a maximum difference of 0.15% for the nLw spectrum with chl=0.01.

5 Summary

None of the issues raised in the introduction have a significant impact on the band averaged values. Thus it was decided to create the Aqua RSR with the following choices:

- Neglect outliers in the out-of-band. All values below 1e-6 were considered outliers. If there were two neighboring values, the value was interpolated. If the value was at the edge of the wavelength range, it was set to 1.1e-6.
- The RSRs between out-of-band and in-band were loglinearly interpolated (main reason: easier to reproduce than inclusion of the Terra RSR).
- The out-of-band values were linearly interpolated (main reasons: physically correct method, visual advantage of loglinear interpolation only apparent when looking at out-of-band RSR in limited wavelength range, e.g. a range of 100nm, see Fig. 3).
- Average detector specific in-band RSR to one RSR per band.

The center wavelengths [nm] calculated from the Aqua RSRs for bands 8-16 are: 416.3, 442.6, 487.5, 530.2, 547.2, 667.2, 678.5, 745.3, 866.9, see table 1 on page 18. Plots of the RSRs are shown in Figs. 4 to 12.

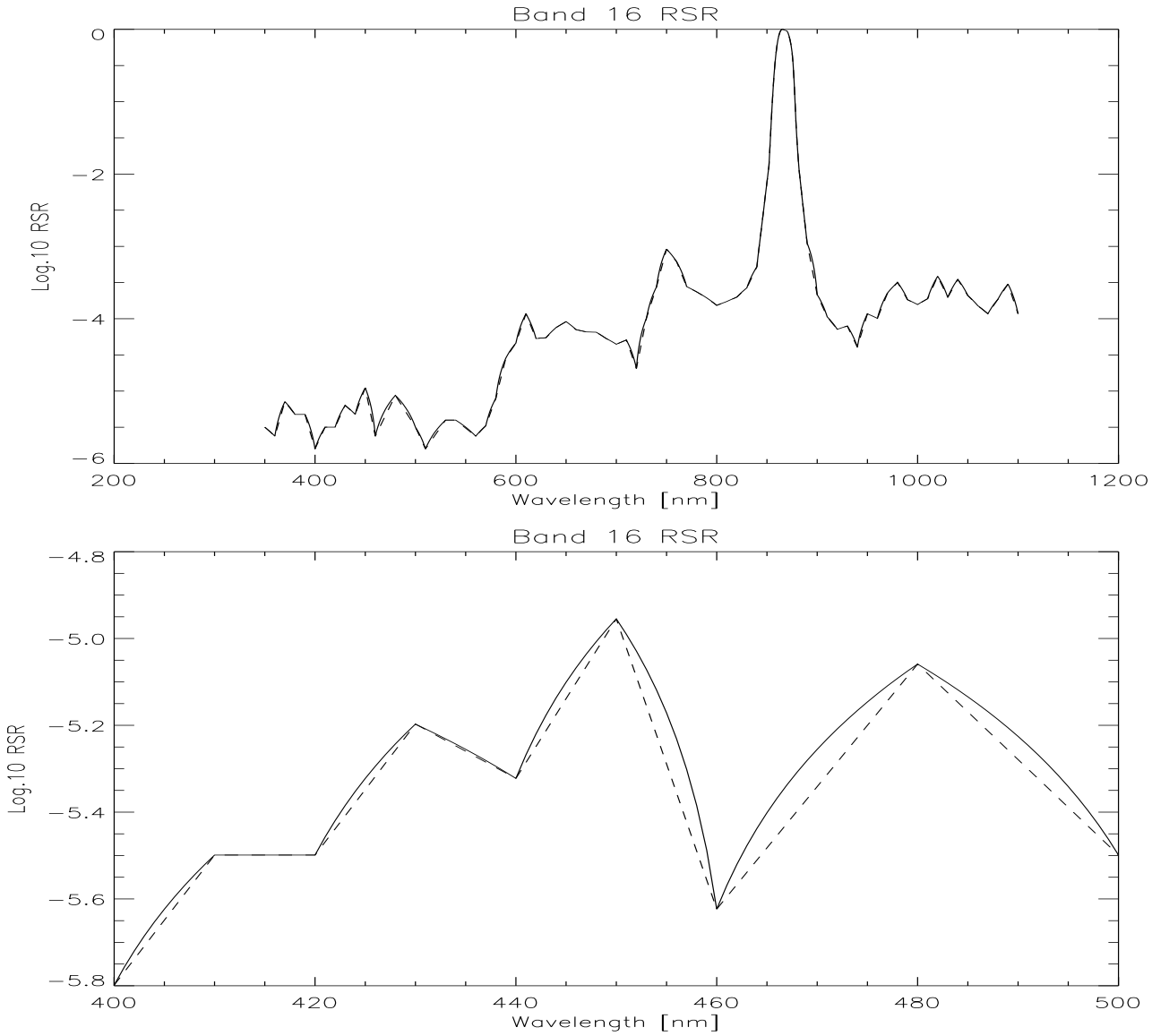

Figure 3: Aqua RSR for Band 16 for linear interpolation in the out-of band (solid line) and loglinear interpolation (dashed line). The difference can only be seen when plotting a subrange of the RSRs, as in the lower plot.

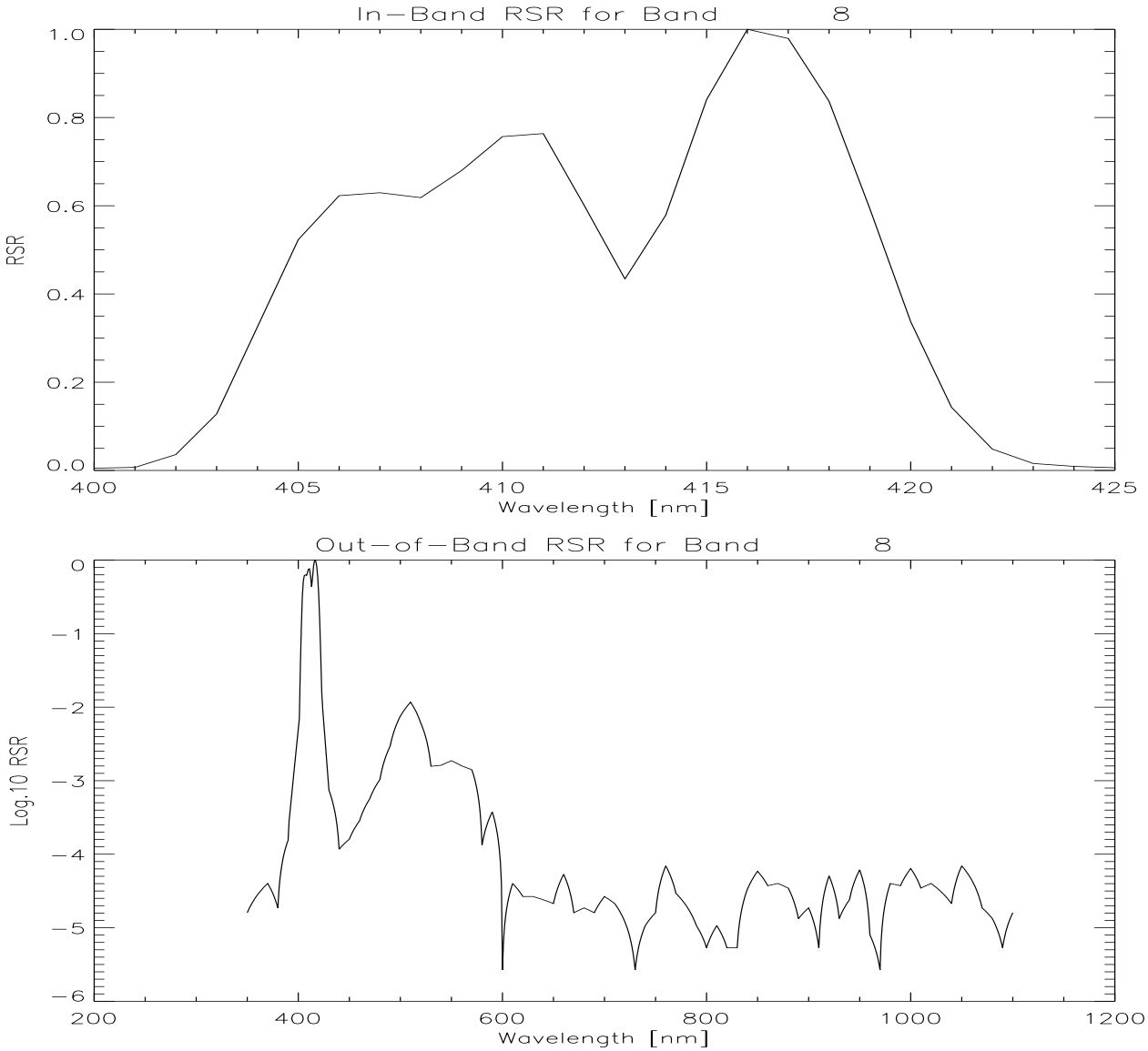

Figure 4: Aqua RSR for Band 8 in-band (top) and out-of-band (bottom).

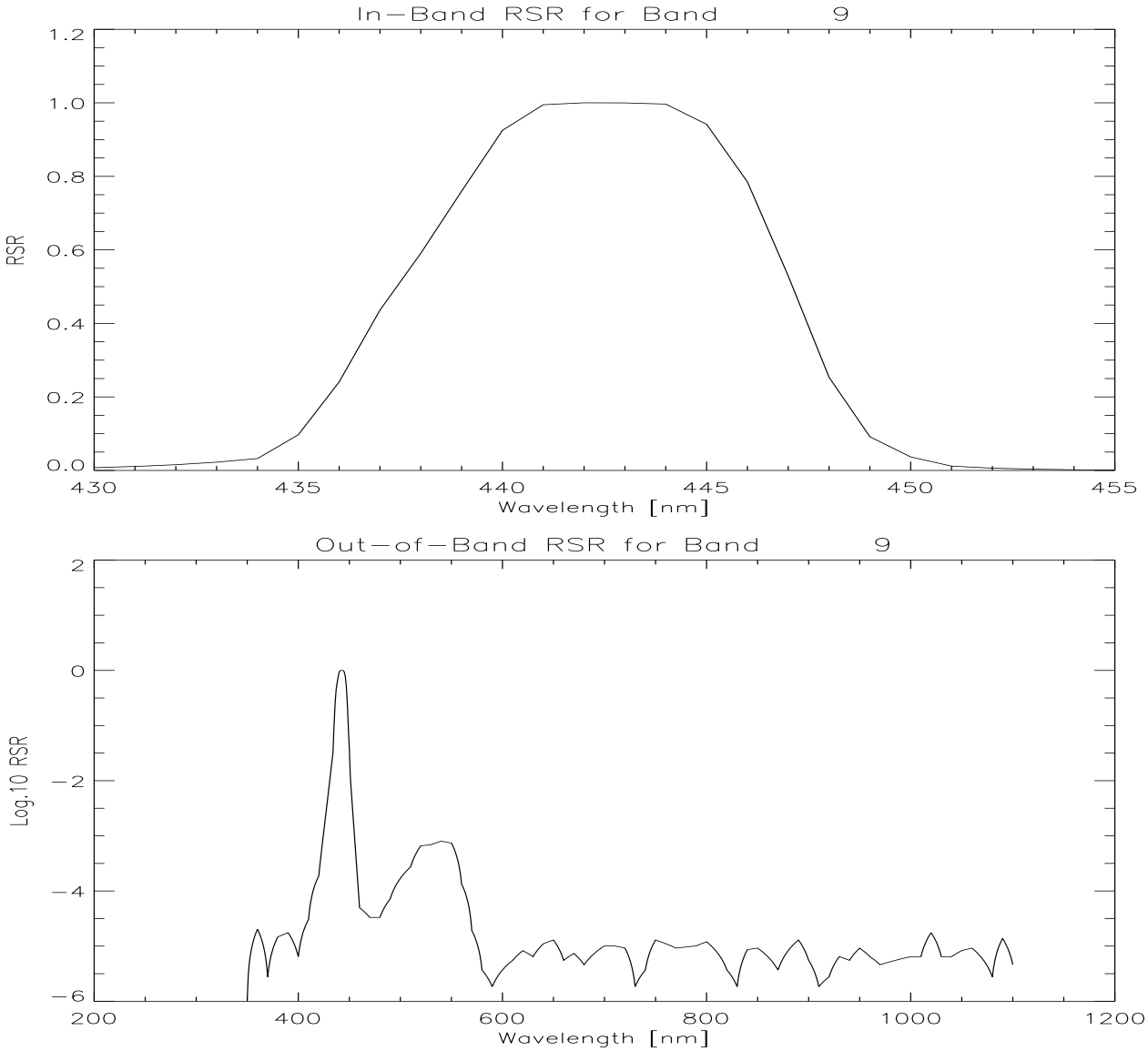

Figure 5: Aqua RSR for Band 9 in-band (top) and out-of-band (bottom).

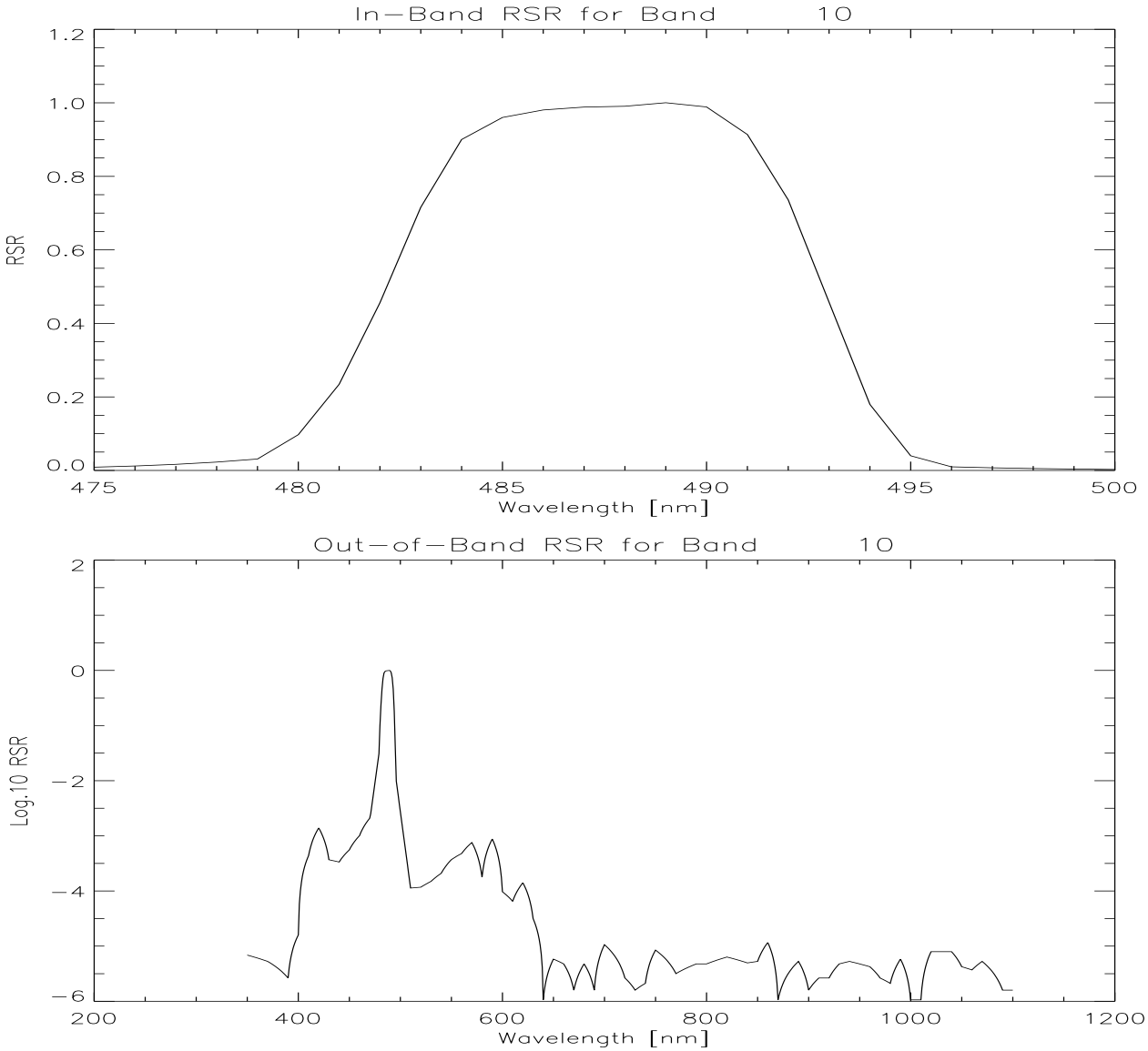

Figure 6: Aqua RSR for Band 10 in-band (top) and out-of-band (bottom).

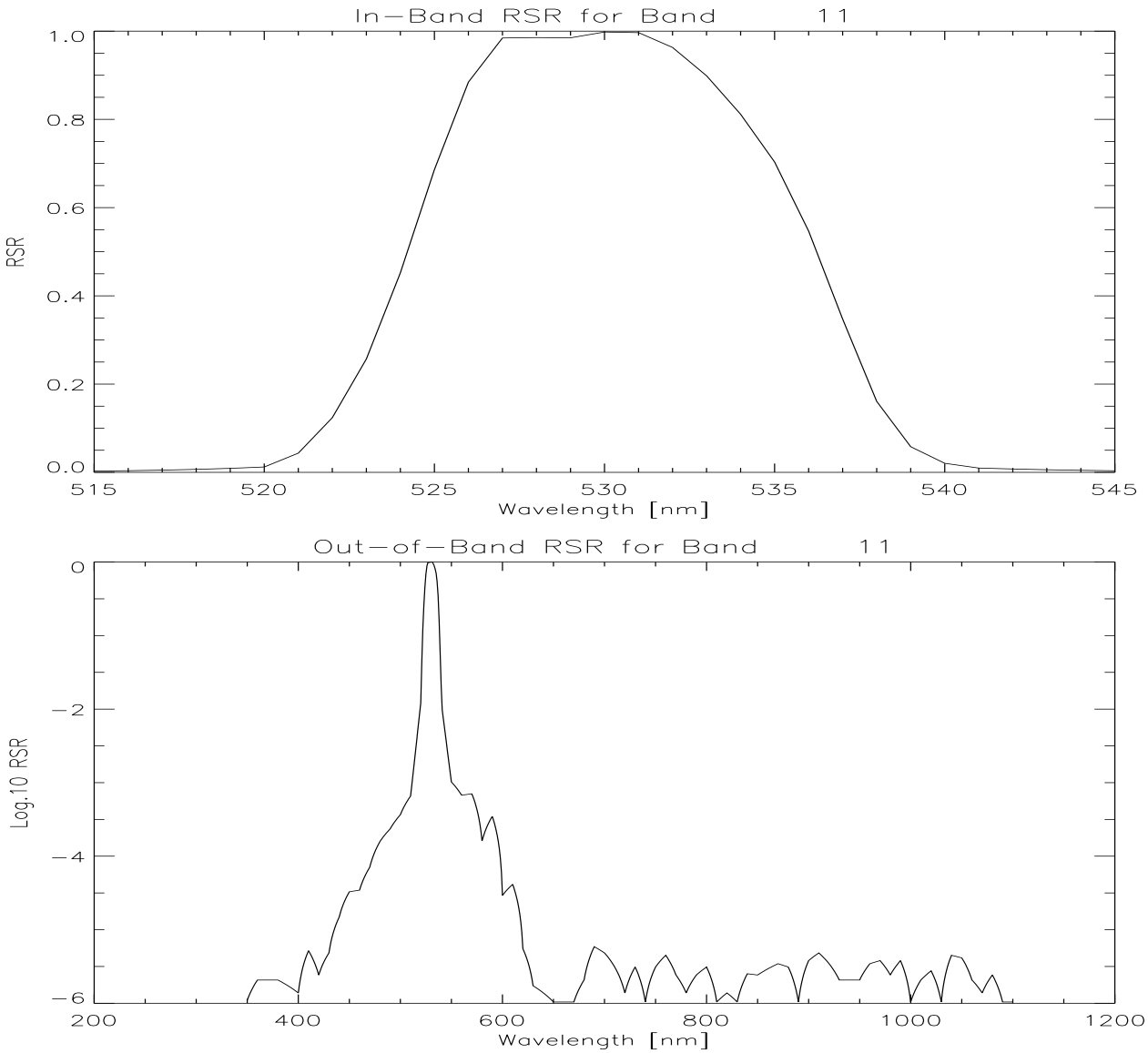

Figure 7: Aqua RSR for Band 11 in-band (top) and out-of-band (bottom).

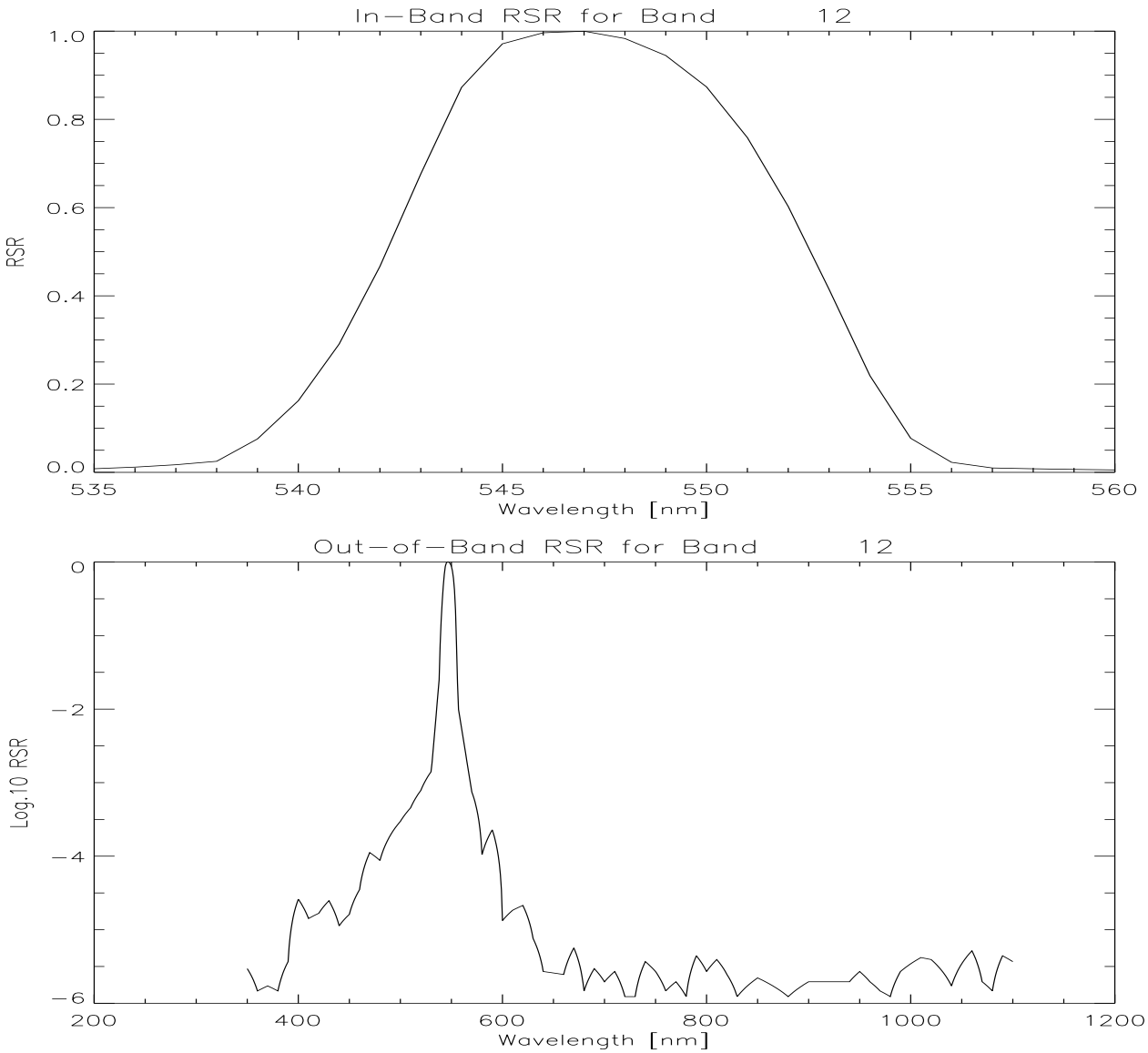

Figure 8: Aqua RSR for Band 12 in-band (top) and out-of-band (bottom).

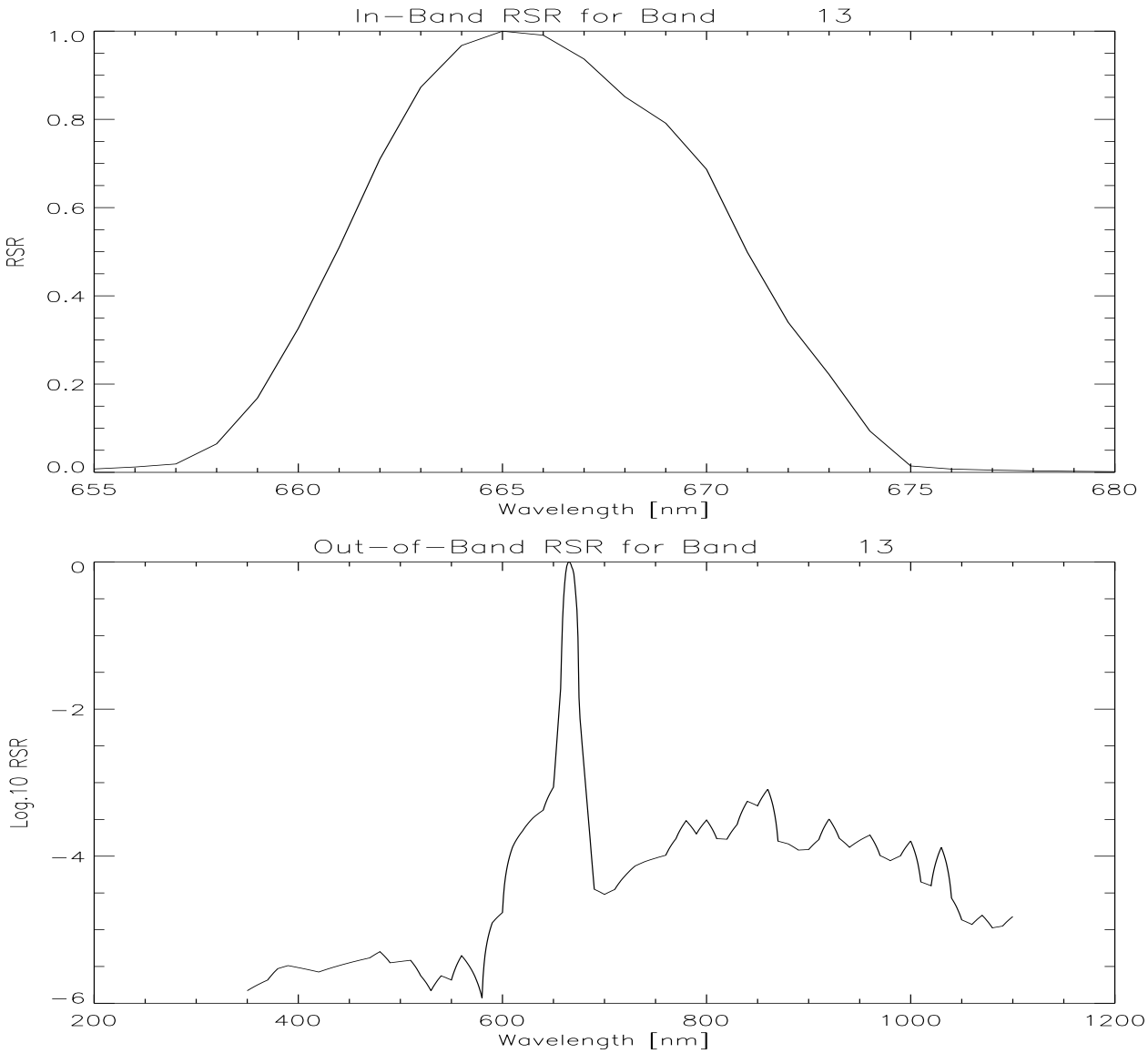

Figure 9: Aqua RSR for Band 13 in-band (top) and out-of-band (bottom).

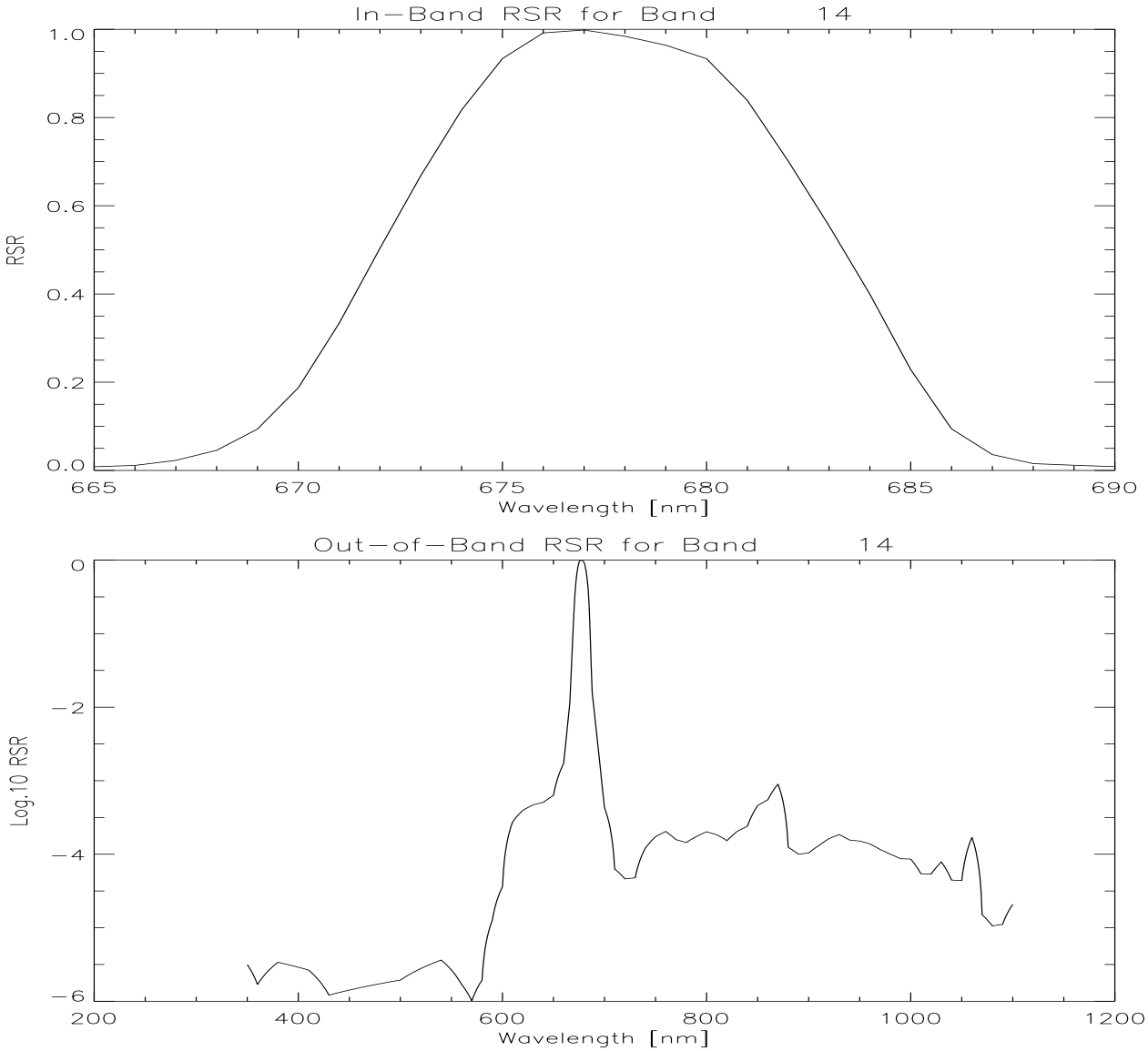

Figure 10: Aqua RSR for Band 14 in-band (top) and out-of-band (bottom).

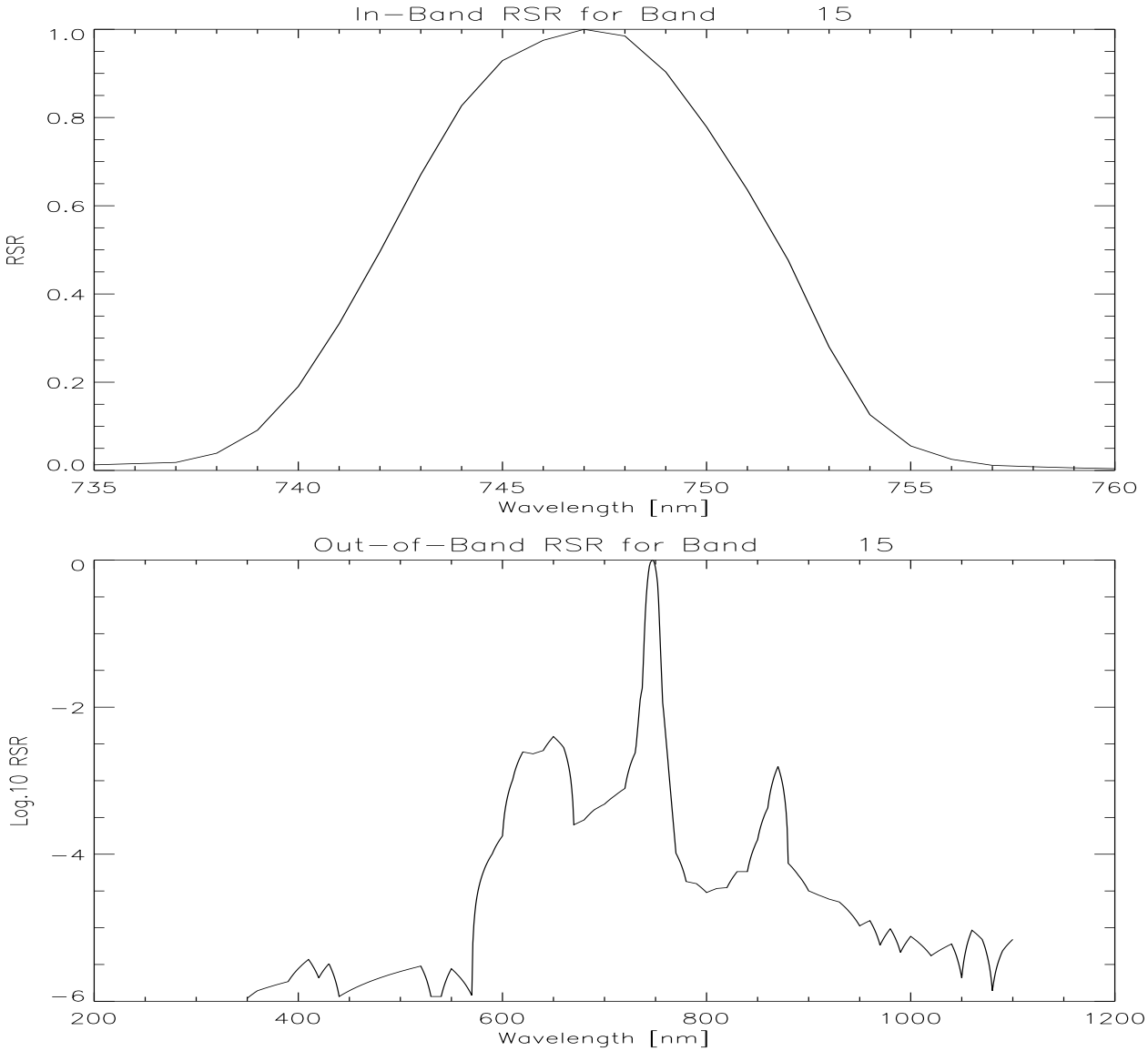

Figure 11: Aqua RSR for Band 15 in-band (top) and out-of-band (bottom).

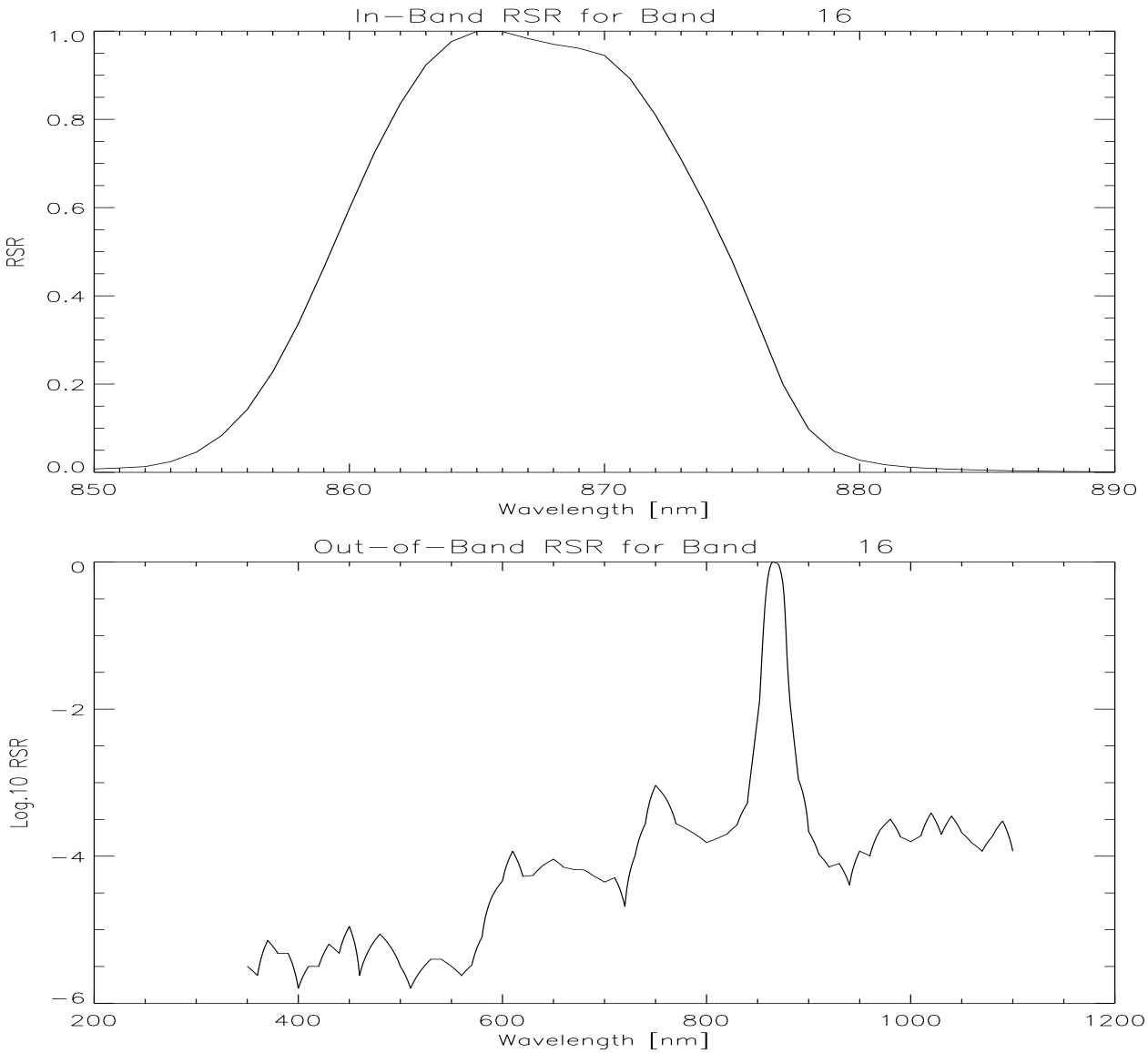

Figure 12: Aqua RSR for Band 16 in-band (top) and out-of-band (bottom).

A Comparison of different RSR datasets

	Aqua norm. in-band	Aqua norm. SpMA	Terra	Aqua for SeaWiFS
Band 8 λ_{CW} [nm]	415.7	412.5	413.7	416.3
Band 9 λ_{CW} [nm]	442.6	442.3	442.7	442.6
Band 10 λ_{CW} [nm]	487.5	487.1	486.9	487.5
Band 11 λ_{CW} [nm]	530.2	530.2	530.0	530.2
Band 12 λ_{CW} [nm]	547.2	547.1	546.8	547.2
Band 13 λ_{CW} [nm]	667.2	668.3	669.1	667.2
Band 14 λ_{CW} [nm]	678.6	679.9	680.8	678.5
Band 15 λ_{CW} [nm]	745.4	746.3	745.8	745.3
Band 16 λ_{CW} [nm]	866.8	866.9	866.5	866.9

Table 1: *Center wavelengths λ_{CW} from RSR datasets provided by MCST and from RSR created in this report for the SeaWiFS group. In-band RSRs have been averaged over all 10 detectors.*

	Aqua	Terra
Band 8 λ_{CW} [nm]	412.5	411.9
Band 9 λ_{CW} [nm]	442.2	442.1
Band 10 λ_{CW} [nm]	487.4	487.0
Band 11 λ_{CW} [nm]	530.1	529.7
Band 12 λ_{CW} [nm]	547.2	546.9
Band 13 λ_{CW} [nm]	666.0	665.8
Band 14 λ_{CW} [nm]	677.6	677.0
Band 15 λ_{CW} [nm]	746.8	746.6
Band 16 λ_{CW} [nm]	866.9	866.3

Table 2: *Center wavelengths λ_{CW} from* in-band-only *RSR datasets provided by MCST, where in-band is defined as greater or equal than 1% of the maximum RSR. RSRs have been averaged over all 10 detectors.*

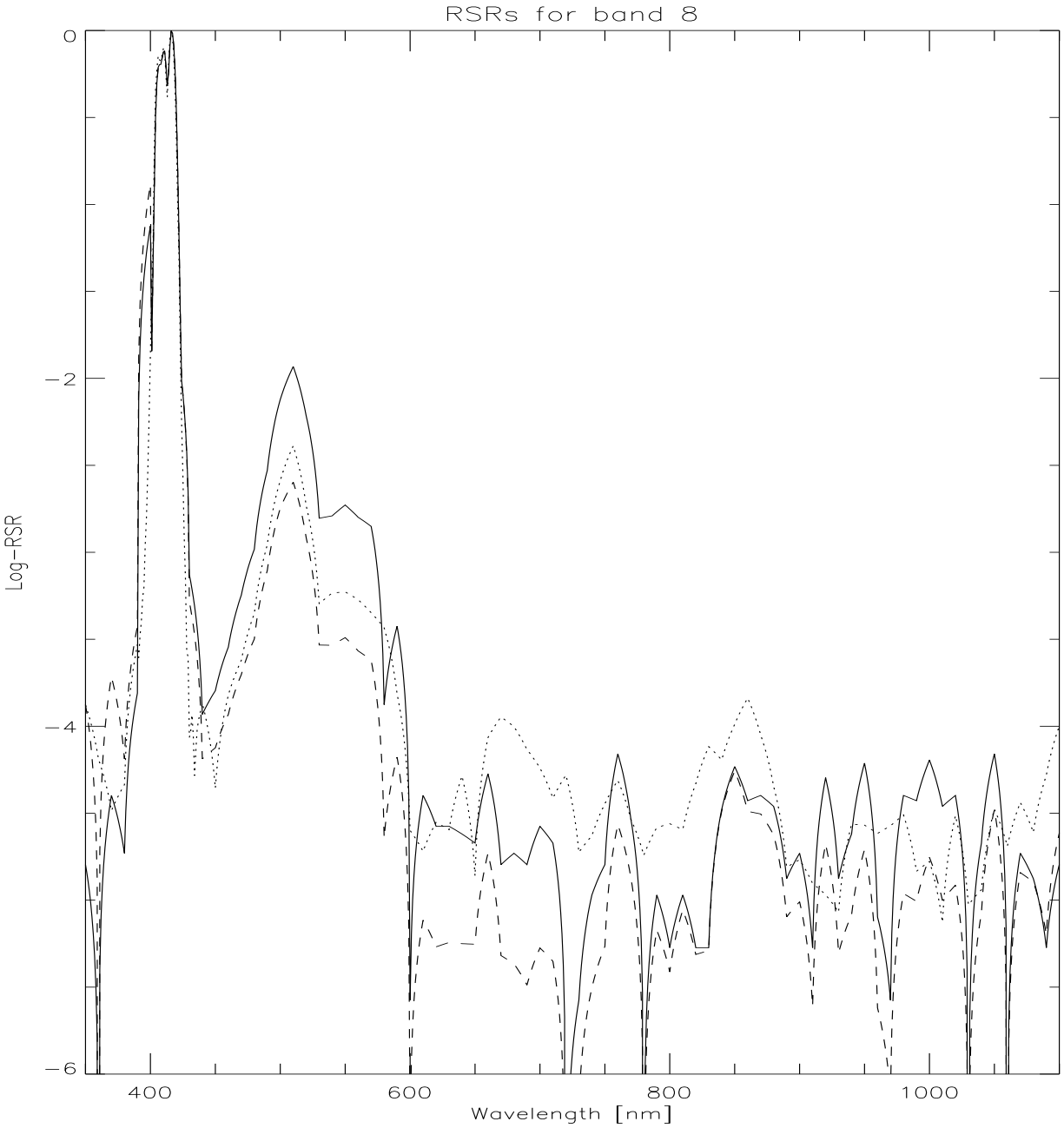

Figure 13: RSRs for band 8 as provided by MCST: Aqua RSR with out-of-band normalized to in-band (solid line), Aqua RSR with out-of-band normalized to SpMA (dashed line), and Terra RSR (dotted line).

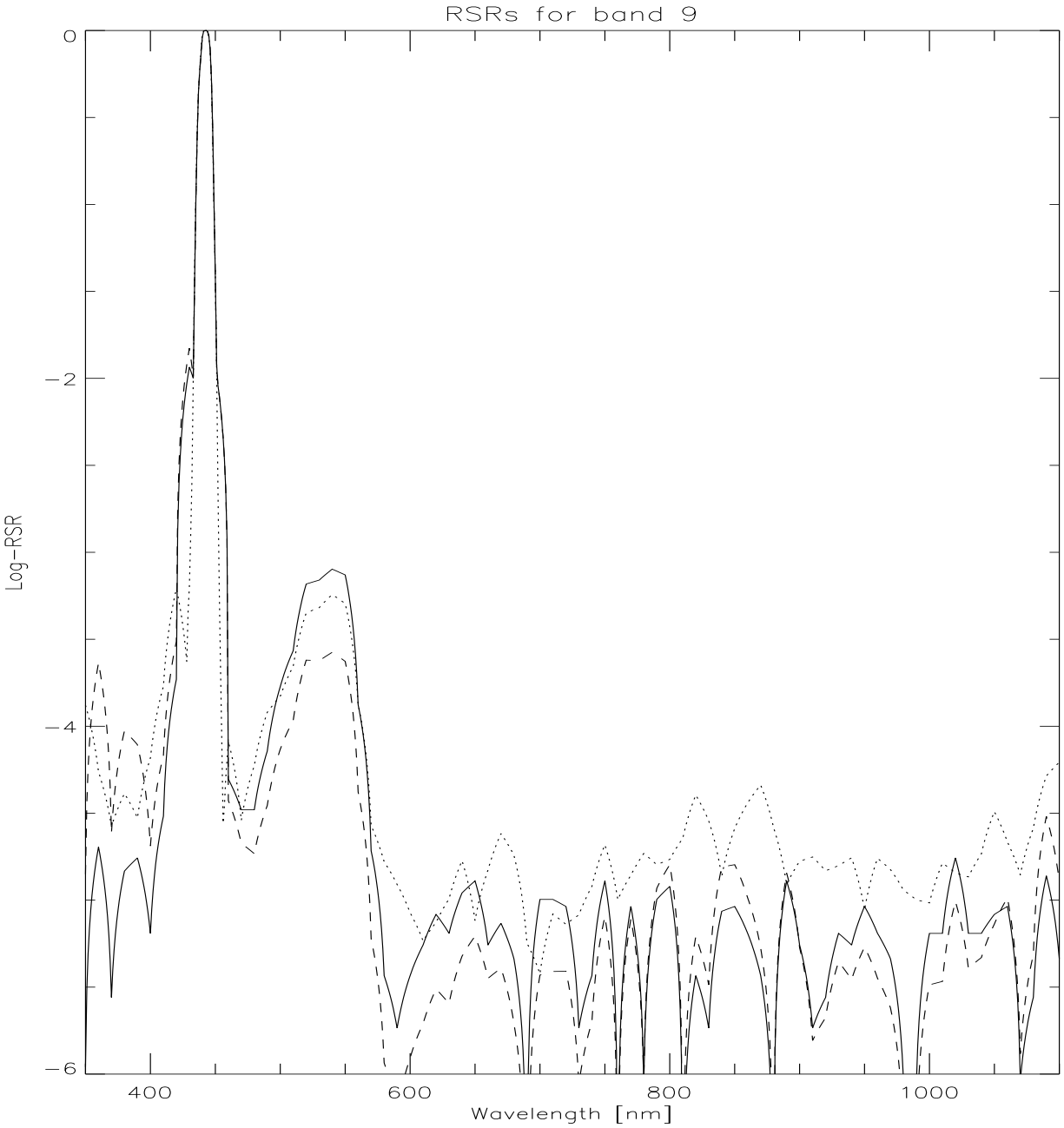

Figure 14: RSRs for band 9 as provided by MCST: Aqua RSR with out-of-band normalized to in-band (solid line), Aqua RSR with out-of-band normalized to SpMA (dashed line), and Terra RSR (dotted line).

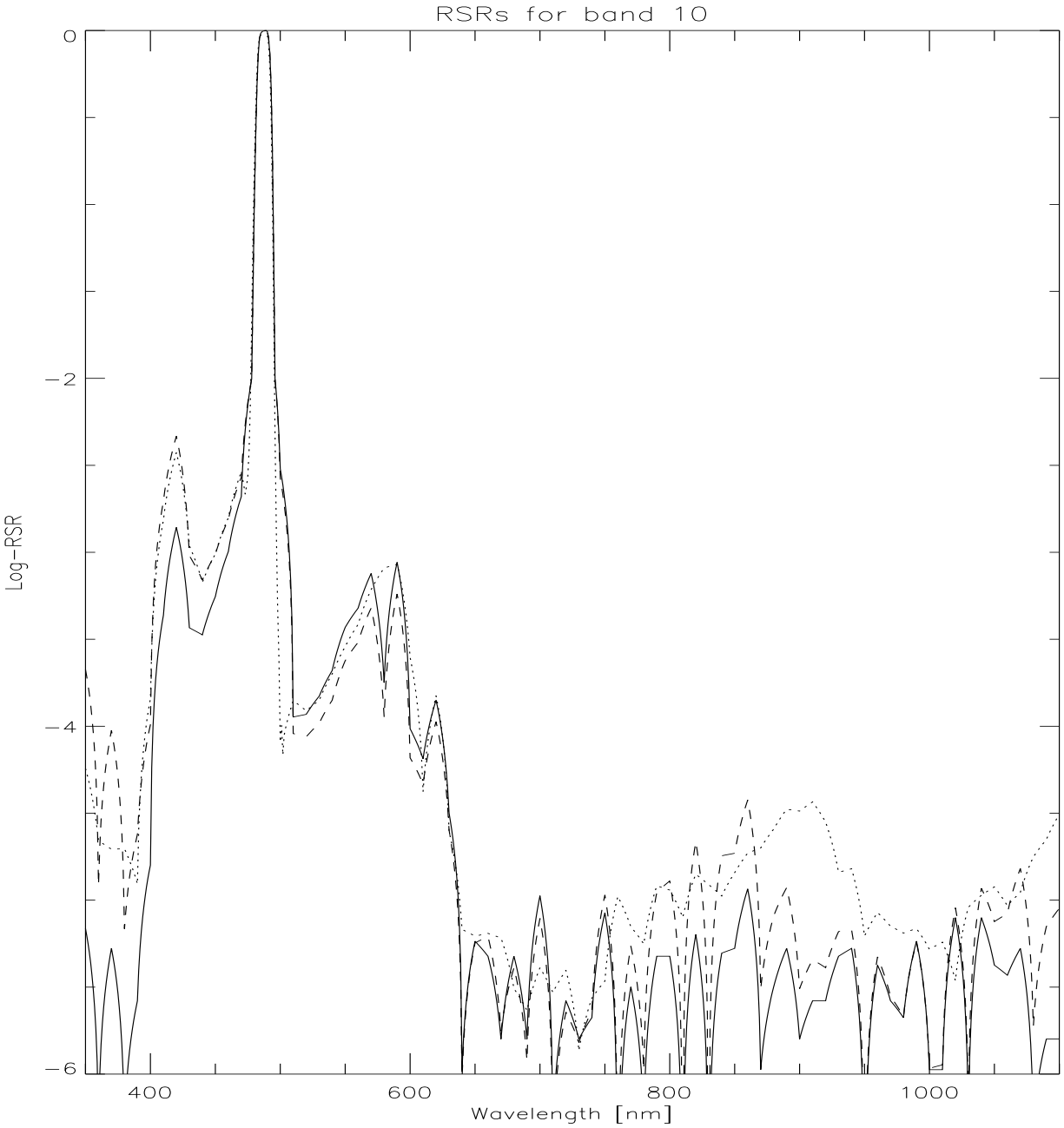

Figure 15: RSRs for band 10 as provided by MCST: Aqua RSR with out-of-band normalized to in-band (solid line), Aqua RSR with out-of-band normalized to SpMA (dashed line), and Terra RSR (dotted line).

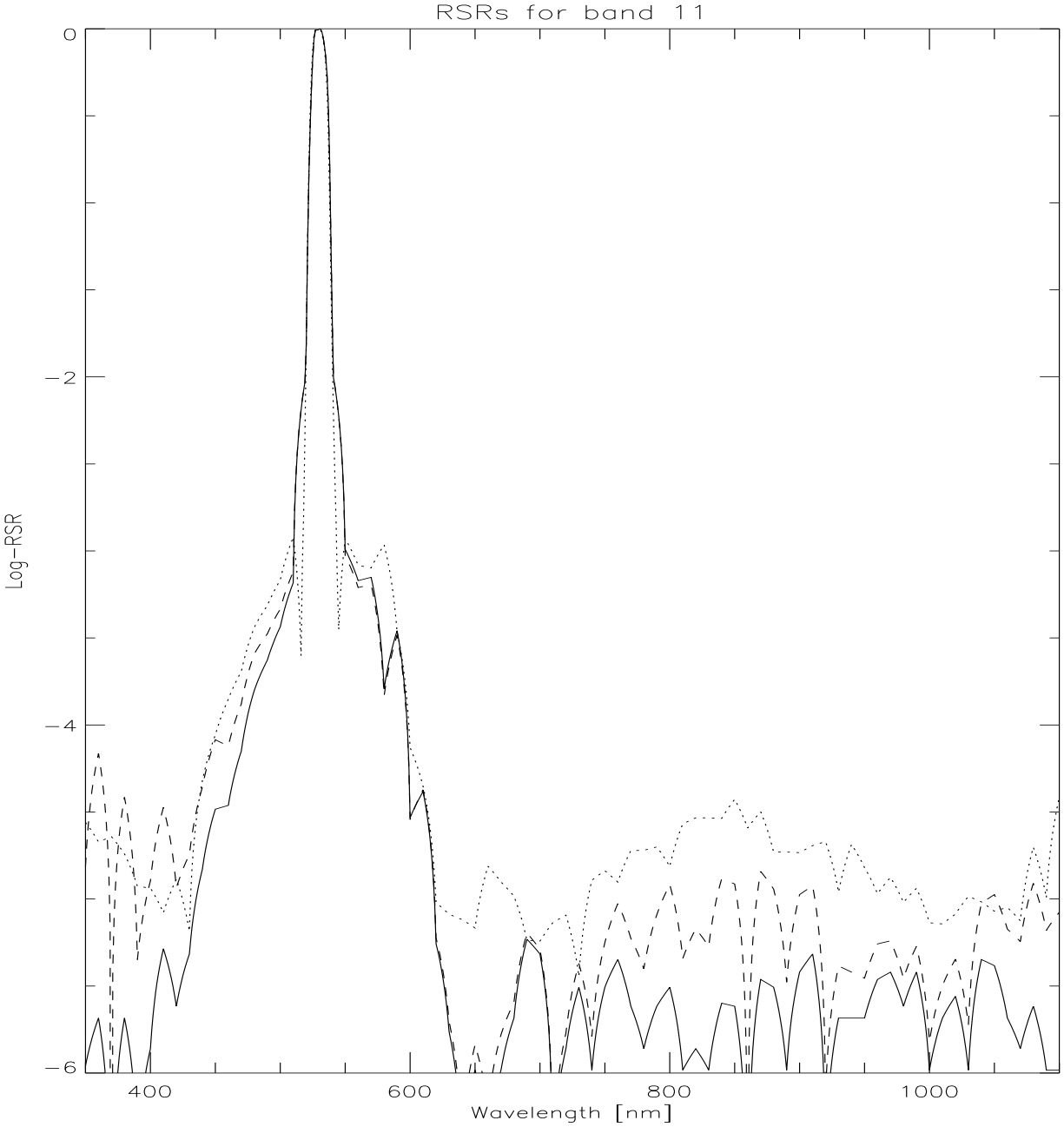

Figure 16: RSRs for band 11 as provided by MCST: Aqua RSR with out-of-band normalized to in-band (solid line), Aqua RSR with out-of-band normalized to SpMA (dashed line), and Terra RSR (dotted line).

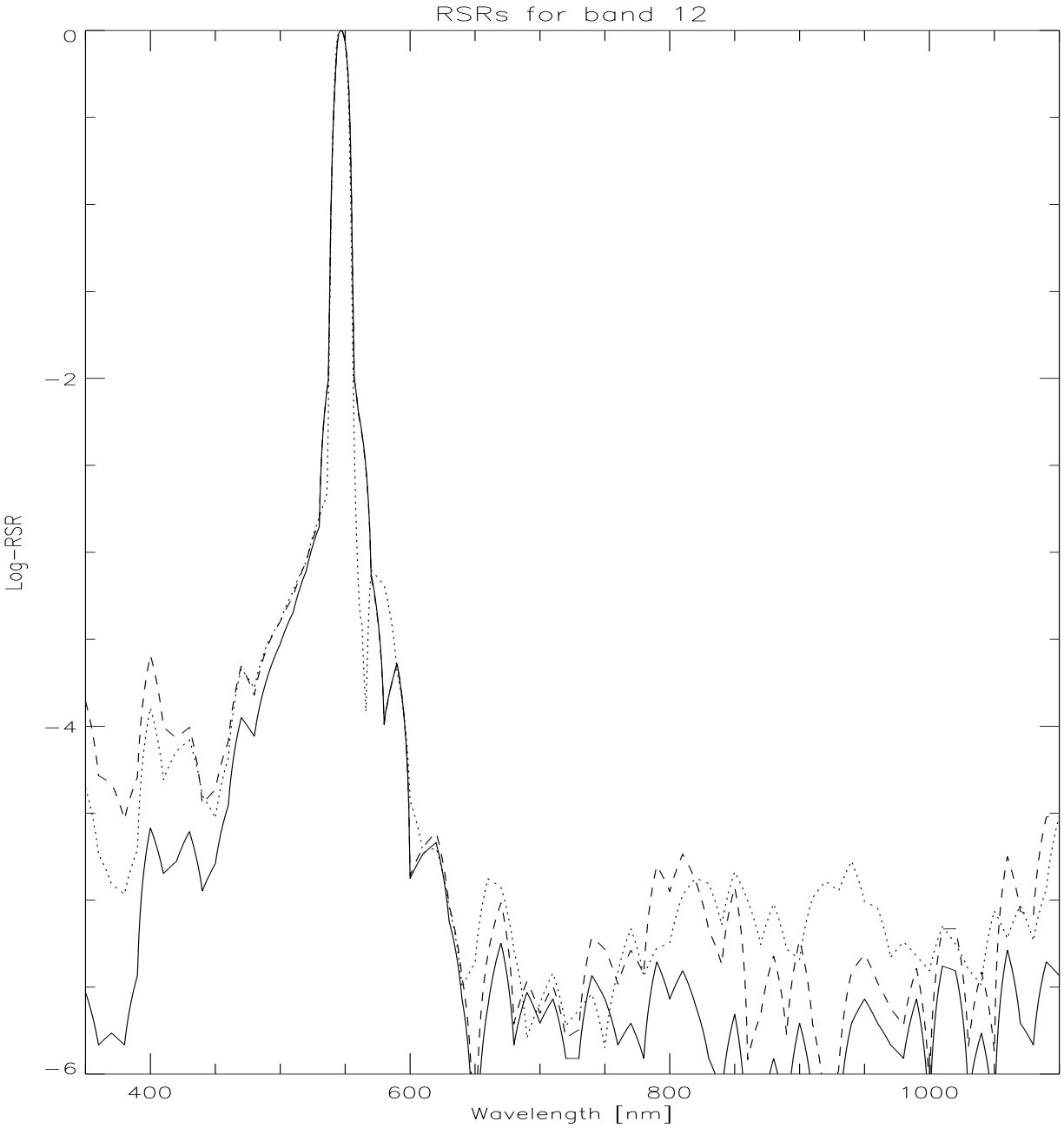

Figure 17: RSRs for band 12 as provided by MCST: Aqua RSR with out-of-band normalized to in-band (solid line), Aqua RSR with out-of-band normalized to SpMA (dashed line), and Terra RSR (dotted line).

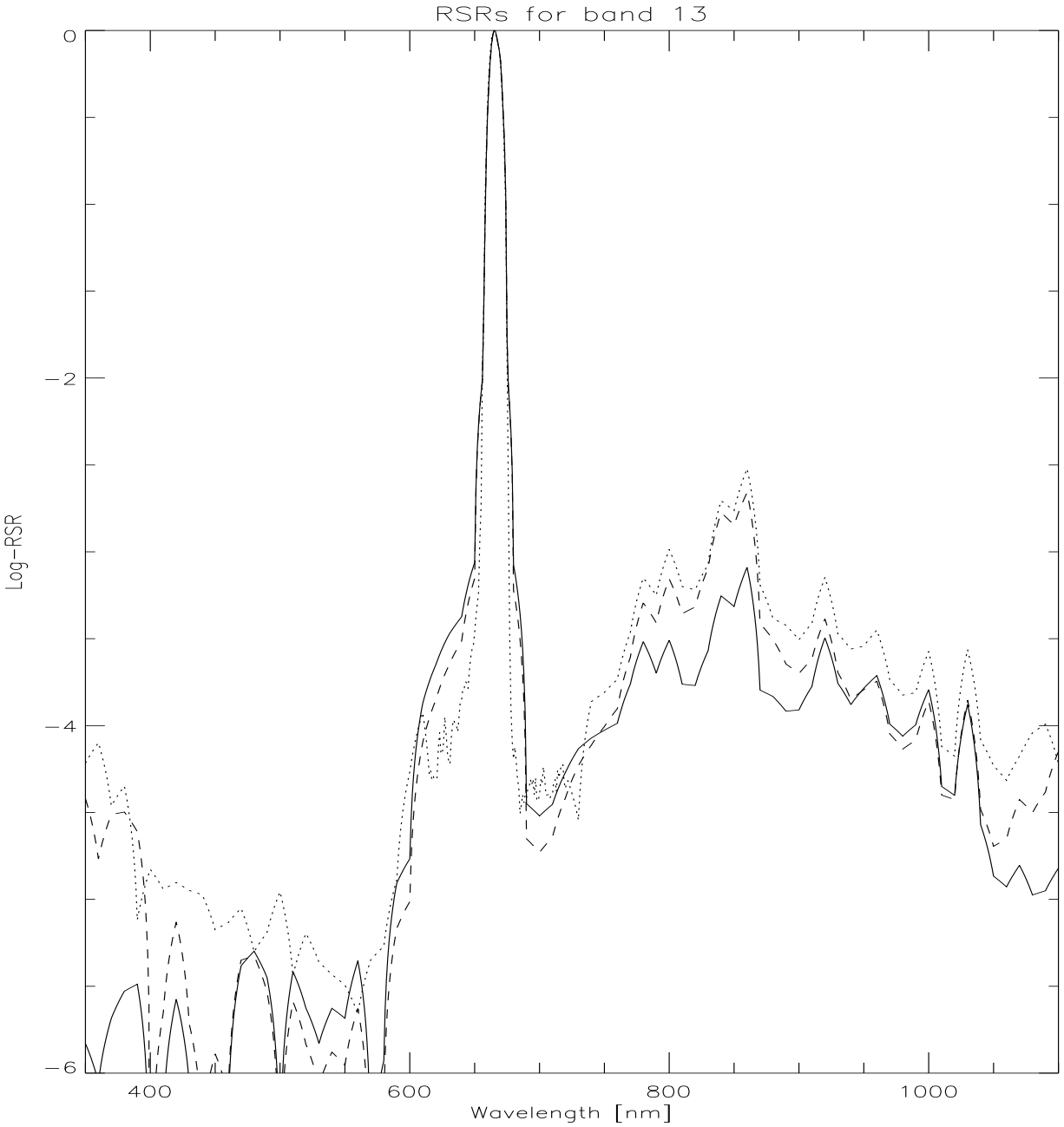

Figure 18: RSRs for band 13 as provided by MCST: Aqua RSR with out-of-band normalized to in-band (solid line), Aqua RSR with out-of-band normalized to SpMA (dashed line), and Terra RSR (dotted line).

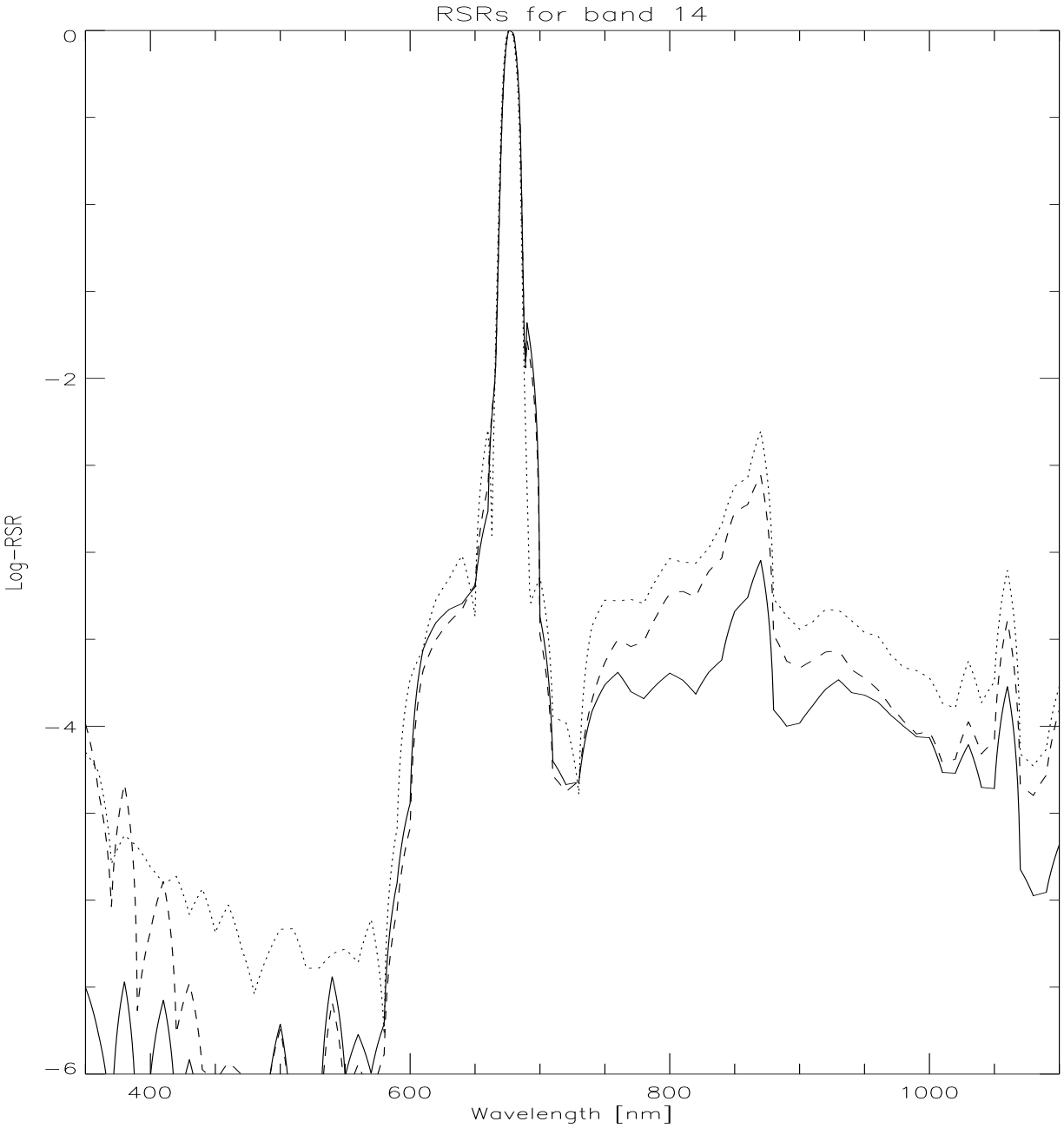

Figure 19: RSRs for band 14 as provided by MCST: Aqua RSR with out-of-band normalized to in-band (solid line), Aqua RSR with out-of-band normalized to SpMA (dashed line), and Terra RSR (dotted line).

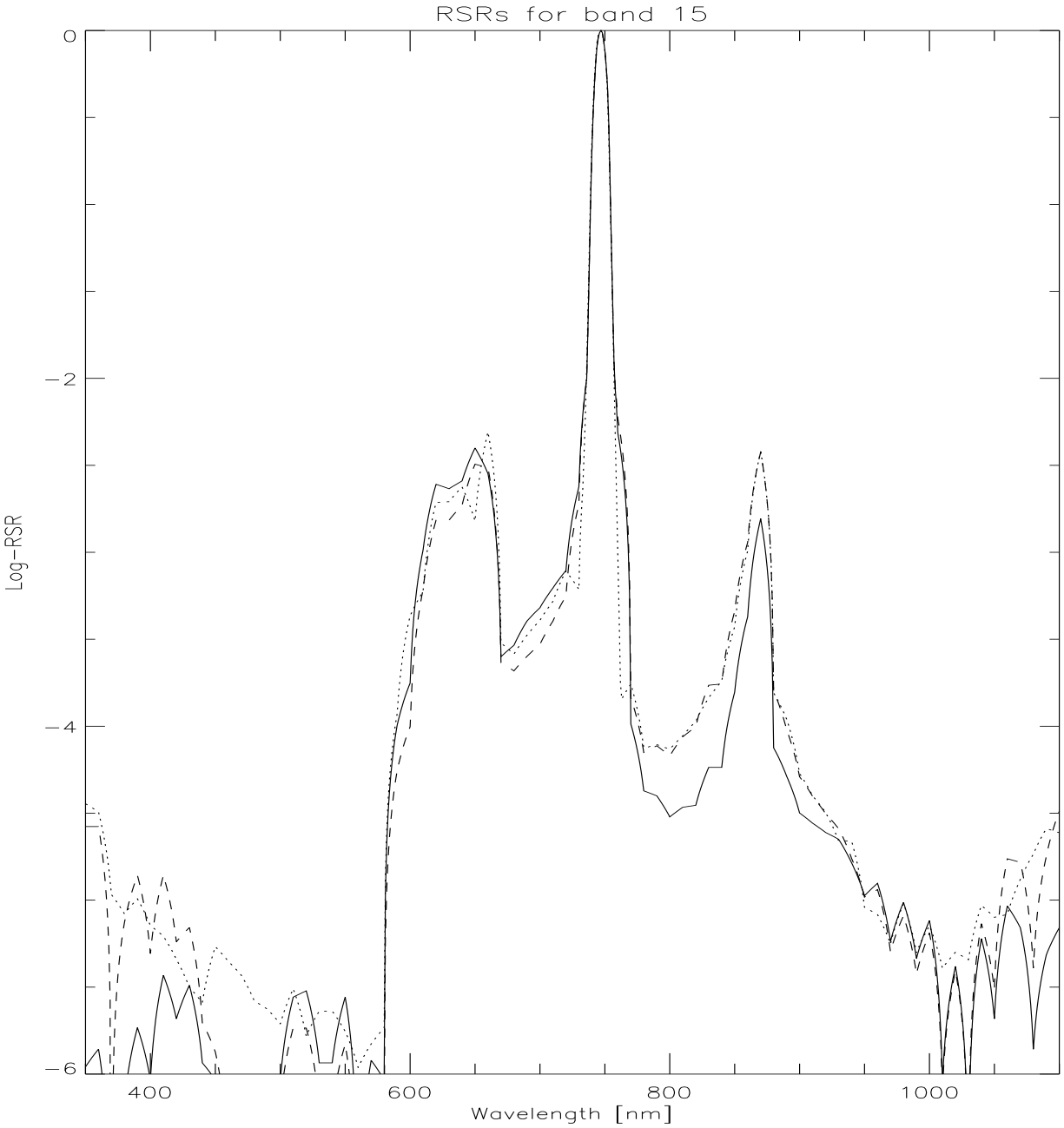

Figure 20: RSRs for band 15 as provided by MCST: Aqua RSR with out-of-band normalized to in-band (solid line), Aqua RSR with out-of-band normalized to SpMA (dashed line), and Terra RSR (dotted line).

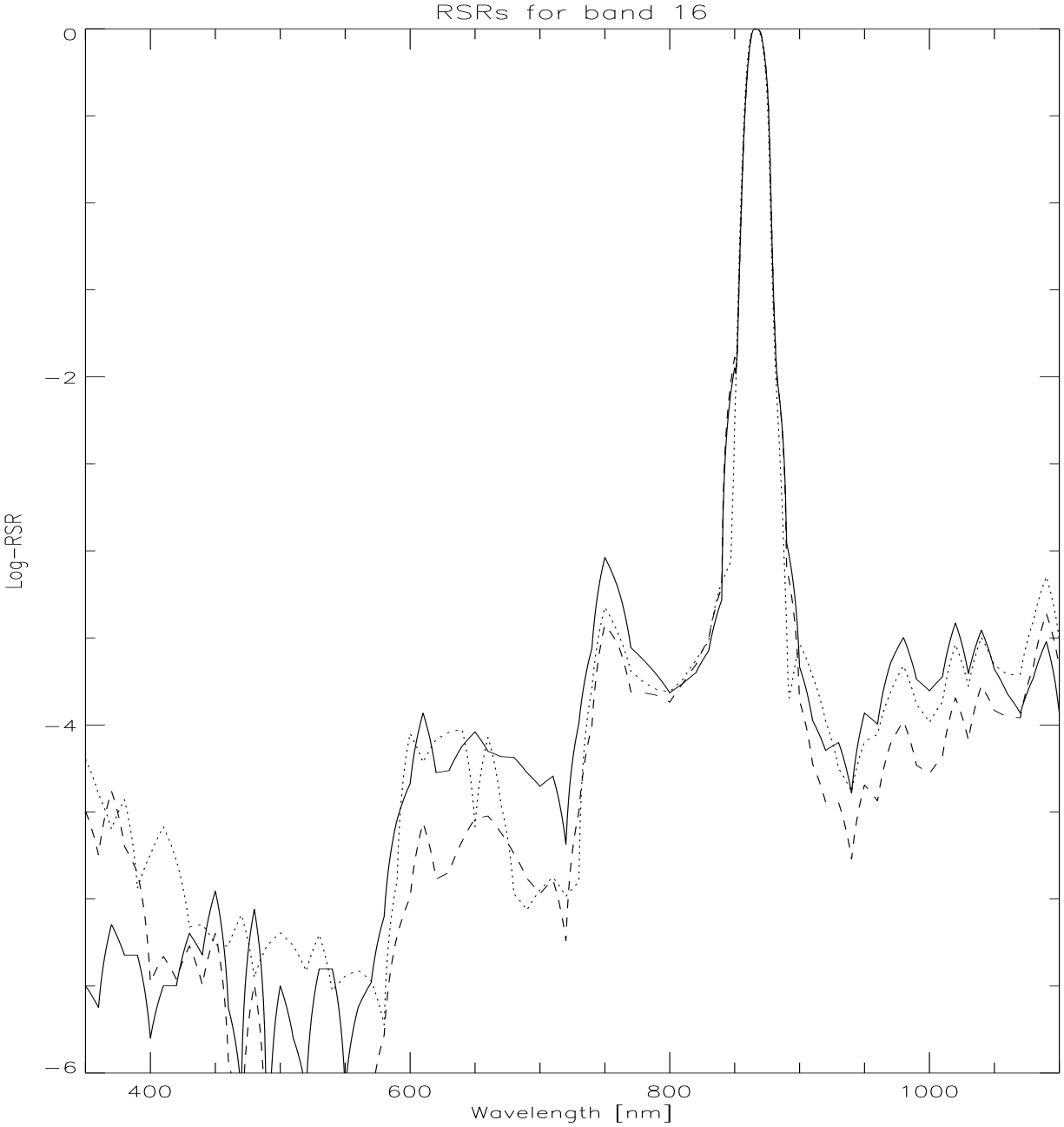

Figure 21: RSRs for band 16 as provided by MCST: Aqua RSR with out-of-band normalized to in-band (solid line), Aqua RSR with out-of-band normalized to SpMA (dashed line), and Terra RSR (dotted line).